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MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

INVESTIGATION
OF
CONCRETE PAVING FORMS

by

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INVESTIGATION OF CONCRETE PAVING FORMS

At the suggestion of the Construction Division the Research Laboratory of the Testing and Research Division undertook an investigation of concrete paving forms with the view of determining whether or not the forms now used by the various contractors possess sufficient strength and rigidity to meet the requirements of present and future concrete pavement construction and, furthermore, if they out should prove to be inadequate, submit recommendations for changes in current specifications which would insure the use of proper forms. Obviously the riding qualities of the pavement may be affected to an appreciable extent by the behavior of the paving forms under loads imposed by the various units of construction machinery, and it seemed desirable to establish specific limits for allowable deflections produced by comparable loads under controlled test conditions.

For this purpose a series of tests for deflection of steel paving forms has been performed similar to those required by several other States. The forms were tested both as simple beams and as uniformly supported beams by applying loads corresponding to the weights of present modern machines that ride on the forms. In the simple beam tests, a vertical deflection of out .190 inch for a beam of 9 foot 6 inch span with a concentrated load of 5500 pounds at the center was tentatively chosen as the maximum allowable limit.

Although testing the forms as simple beams with a concentrated load at the center of span may be open to some criticism from the standpoint of measuring actual performance in service, it does provide means of selecting the most desirable forms.

The investigation revealed that, on the basis of the testing method employed, many of the forms in present use are not sufficiently rigid to out

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meet the requirements of future pavement construction. The trapezoidal forms tested were, in general, superior to the L forms in rigidity, but none of the commonly used types is of an ideal section since they all carry their load eccentrically with respect to the base. Both of the trapezoidal forms tested met the tentative requirement of .150 inch maximum deflection under the given load. On the other hand, only five of the sixteen forms of L section for which test results are recorded gave deflections of less than .150 inch under the same conditions. In order to successfully meet the requirements of this test, L forms must be constructed of plate of 1/4 inch minimum thickness and, in addition, must be designed and fabricated for maximum rigidity. Trapezoidal forms must be contructed of metal at least 3/16 inch in thickness in order to withstand conditions of handling and use.

A consideration of the general problem also indicates that a limit of 1/8 inch should be set on the allowable vertical deflection of the form joints under the load imposed by the heaviest machine carried on the forms, and that lateral deviations, both in the planeness of the face of the form and in the position of the joint, should be restricted to a maximum of 1/4 inch.

The report gives a description of the materials and testing procedures used, with a discussion of the results obtained and a recommendation for specific changes in the present specification governing the use of concrete paving forms. As a matter of interest, the report contains also some observations on old forms which have been in service for various periods and a comparison of these forms with those of recent make.

DESCRIPTION OF TESTS

As a preliminary ~~The first~~ step in this investigation ~~was~~ a study was made of typical paving form specifications in current use by other State Highway Departments. Extracts from these specifications and also those of Michigan are summarized in Table 1. Only ten States and the District of Columbia are listed in this table, as other States have similar specifications or none at all. All of the States listed include a rigidity requirement in their specifications ranging from "visible springing or settlement" under the finishing machine to a maximum deflection of .01 inch in a four foot span under a center load of 1700 pounds. The present specifications of our own Department call for the use of forms "of an approved section, which will insure their rigidity under the finishing machine". It is evident that there is need of a standard specification and method of test based on actual physical measurements and if such specifications are to have definite meaning.

At first a maximum allowable deflection of 1/8 (.125) inch under a center load of 3500 pounds was tentatively chosen for the purpose of standardization for two reasons. First, the present Department specifications limit the deviation from a true plane of the finished pavement to 1/8 inch in 10 feet; the same limit also applies to vertical variations in the top surface of the forms. Second, two other States, Nebraska and Pennsylvania, have specifications limiting vertical deflections under a 1700 pound load to .125 inch for a 10 foot span and .01 inch for a 4 foot span respectively. The latter is equivalent to a deflection of .156 inch in a 10 foot span under the same load.

TABLE 1

EXTRACTS FROM SPECIFICATIONS FOR CONCRETE PAVING FORMS IN USE BY VARIOUS STATES

State	Minimum Width Base Inches	Minimum Width Top Inches	Minimum Length-ft. (Except curves)	Form Pins Min. No.	Form Pins Min. Diam. Inches	Section to be Approved	Planeness of Surfaces Maximum Lateral Deviation	Planeness of Surfaces Maximum Vertical Deviation	Minimum Gage or Thickness Inches	Minimum Weight Per Foot lb.	Joint Efficiency	Rigidity Requirements
Alabama	8	-	10	3	-	yes	1/4	1/8	-	-	Shall be free from play or movement in any direction and provide a perfect support and connection	Deflection of not more than 1/4" in 10' when tested as a simple beam under load equal to finishing machine
California	8	-	-	3	-	-	1/4	1/8	-	10	Vertical movement not more than 1/8"; horizontal movement not more than 1/4"	Shall be of such section and of sufficient rigidity to prevent springing under the weight of the subgrade and paving equipment or pressure of pavement when placed
Colorado	8	-	-	-	-	yes	0	0	-	-	------	Shall withstand impact and vibration from a 5,000 lb. finishing machine without visible springing or settlement
Connecticut	7-9	2	10	-	-	yes	1/4	1/8	8 for L type 12 for Trap.	-	Shall be connected in such a manner that the deflection under load at the joints will be no greater than elsewhere	Shall have no vertical or horizontal movement when subjected to the load of the finishing machine
District of Columbia	8	-	10	3	-	-	1/4	1/8	7/32	17	------	Shall withstand without visible springing or settlement, the weight, impact and vibration of the finishing machine
Florida	8	-	10	-	-	yes	1/8	1/8	9 for L type 12 for Trap.	8.0-6" 8.5-7" 9.0-8" 9.5-9"	------	Shall resist the pressure of the concrete and finishing machine or finishing tools without springing
Indiana	8	-	10	-	-	yes	1/4	1/8	-	15	Shall be free from movement in any direction	Shall resist without springing or settlement, pressure of concrete, and the impact and vibration of the finishing machine or subgrader
Iowa	-	-	-	-	-	-	-	-	-	-	-------	Deflection of not more than 1/4" in 10' when tested as a simple beam of 9'6" span under a load of 1700 pounds
Michigan	8	-	10	3	-	yes	-	1/8	-	-	Locked joint free from play or movement in any direction	Shall be of an approved section which will insure their rigidity under the finishing machine
Nebraska	-	1-3/4	-	-	-	yes	-	-	-	-	-------	Maximum deflection of not more than 1/8" in 10' when tested as a simple beam under a center load of 1700 lbs.
Pennsylvania	8	-	10	3	7/8	yes	1/8	1/8	-	-	Positive locking devices which will permit neat, tight joints which will not deform under impact, vibration or thrust	Deflection of not more than 0.01" in a four foot span under a center load of 1700 pounds

Although the test load used by several/other ~~the two~~ States is 1700 pounds ~~in both cases~~, which corresponds to the wheel load of a considerably lighter machine, it is evident that in order to maintain the same standards while using heavier machines on the forms the test load must be increased without permitting a corresponding increase in maximum deflections. This means that sturdier forms must be provided in order to properly support the greater load.

The test load of 3500 pounds used in the present investigation was arrived at by dividing by four the total weight (14,000 pounds) of the heaviest finishing machine in use at the present time, and represents the vertical force exerted by a single wheel. One type of spreading machine weighs 15,600 pounds, but since it has not been used frequently by contractors because of its extreme thrust and subsequent damage to paving forms it was not considered in these tests. Also, its load is distributed over six wheels which would probably reduce the individual wheel load below 3500 pounds.

The original tentative limit of .125 inch maximum deflection was later extended to .150 inch as the tests progressed when it became evident that the latter figure represented a fairly definite line of demarcation between forms of desirable and undesirable characteristics. It should be kept in mind that the deflection requirement tentatively adopted in the simple beam test is more or less arbitrary and has little relation to actual deflections encountered in practice except under extreme conditions of subgrade support. The purpose of the simple beam test is to eliminate the use of poorly designed, unstable forms. That the requirements of this test are not unreasonably severe, however, is demonstrated by the fact that seven of the eighteen forms tested

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singly met them easily with deflections well below the maximum allowable limit considered in this investigation.

Forms Used in the Tests

Standard forms commonly used in concrete highway construction are divided into two general classes according to their cross sections, namely, L shaped and trapezoidal forms. There were three makes of the L type forms and one of the trapezoidal type represented in this study. The three makers of the L type forms are referred to in the report as A, C and D; B refers to the manufacturer of the trapezoidal form. In order to evaluate the performance of the forms in actual use by various contractors a number of used sections representative of the different makes and sizes were borrowed from their owners. These forms varied in degree of preservation from almost unserviceable to almost new. However, after preliminary tests of these used forms, ~~revealed that, of all forms available at the time, only the two of trapezoidal section met the original tentative limitation of a maximum deflection of 1/8 inch when tested as simply supported beams~~, it was deemed advisable to procure unused forms and these were also tested as simple beams.

Simple Beam Tests

All forms were tested as simple beams of 9 foot 6 inch span with a concentrated load of 3500 pounds applied vertically at the center of the span. It was discovered early in the investigation that the forms warped laterally when tested as simple beams. To eliminate this warping, and thus obtain the true vertical deflection, some forms were tested in pairs, clamped face-to-face.

out

Single Forms as Simple Beams: Figure 1 shows the general test setup of a trapezoidal form being tested as a simply supported beam of 8 foot 8 inch span. The ends of the form rest on one inch half round steel bars which in turn rest on unyielding supports. The load was applied in three increments of 1000 pounds and one of 500 pounds in order to obtain data for load-deflection curves. The applied force was measured by a proving ring with a ten-thousandth dial and the deflections of the form were measured by one-thousandth dials. Figure 3 is a sketch of an L type form showing the positions of load and deflection measurements for the simple beam tests.

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Simple Beam Tests of Two Forms Clamped Face-to-Face: As previously stated, in order to obtain a more reliable measure of vertical deflections, some forms were tested in pairs to eliminate the warping tendency under a vertical load. Figure 2 shows the general setup for testing two forms clamped face-to-face. The setup (is) was similar to that for the single form test except that two forms and a total load of 7000 pounds were used.

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Tests on Sand Subgrade

In order to obtain data as to the performance of the forms under conditions approaching as nearly as possible those of actual service the forms were set up on a sand subgrade 24 inches deep which had been placed in the laboratory in connection with another experiment. The sand was obtained from a Bellefontaine soil in the vicinity of Lansing and had the following sieve analysis:

Sieve No.	10	40	200
Per cent Passing	99.5	86	1.5

Blanchard [illegible]

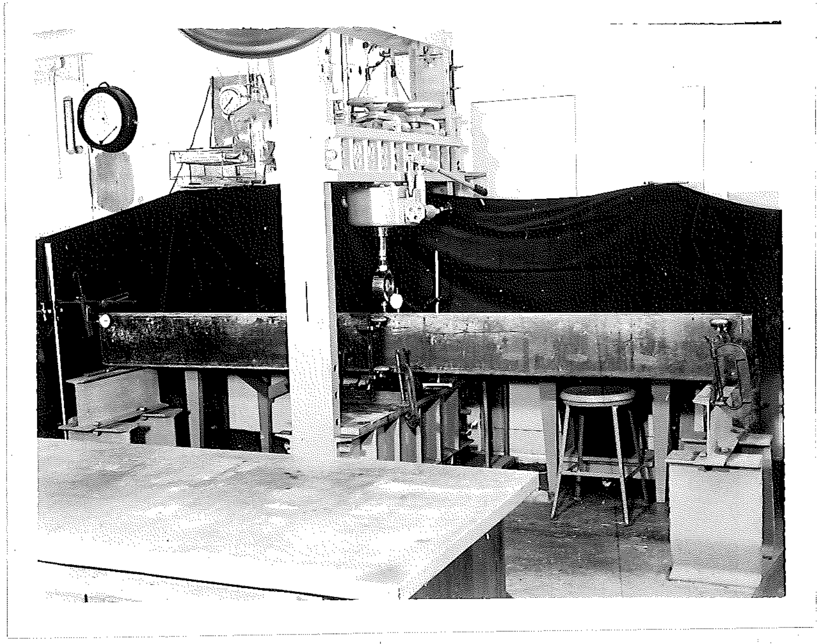

Figure 1. General view of setup for testing single forms as simply supported beams.

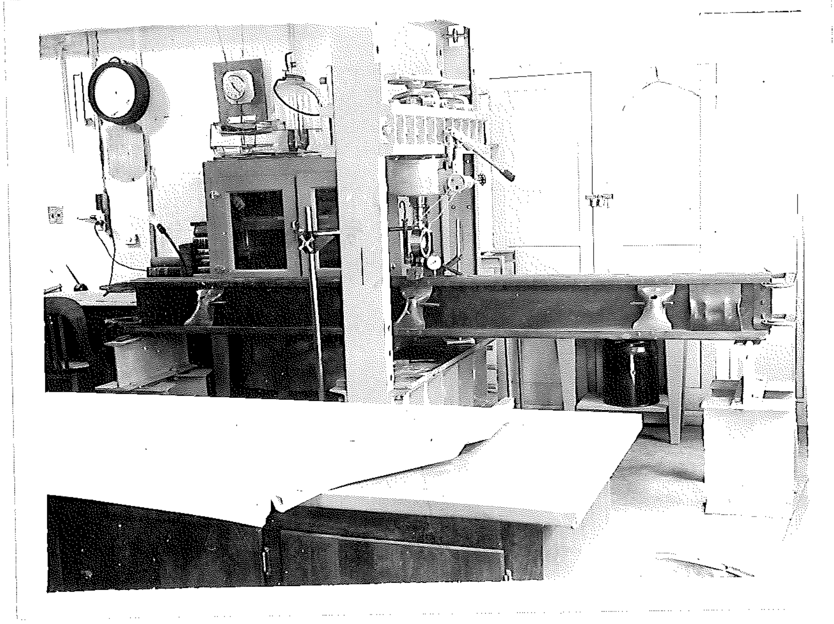

Figure 2. General view of setup for testing two forms clamped face-to-face.

DEFLECTION MEASUREMENTS
FOR L TYPE FORMS

DIALS AT A-B-C-A_1-A_2

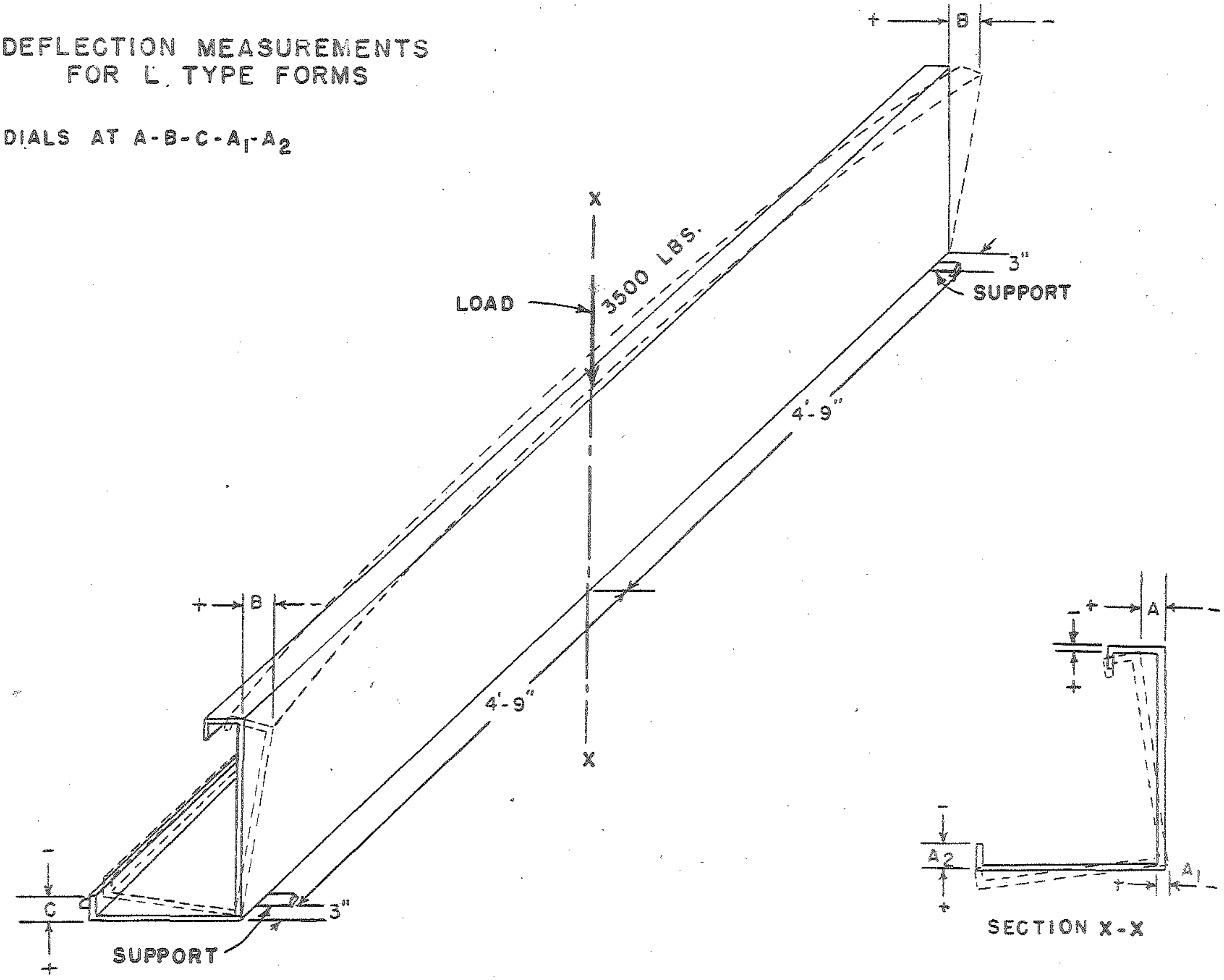

FIGURE 3

and [illegible]
[illegible]

Two forms were set up level, in a straight line, and securely connected in order to obtain an indication of their performance as uniformly supported beams and also to obtain their relative joint efficiency. Since the forms were tested in pairs these tests could be made only on the types of which there were pairs available. These included the A, B and D makes. The dial holders were hinged on the box containing the subgrade soil. The corner of the ell of these holders rested on 4 inch x 4 inch posts which extended to the concrete floor below the subgrade. The entire dial assemblies were set clear of the soil to minimize any disturbance of the dials from possible movement of the subgrade soil during the loading tests.

Prior to every test the forms were tamped by means of a mechanical tamper. Loads were applied by a hydraulic jack and measured by a proving ring. Figure 4 shows the general test setup with one loading device (jack-dynamometer assembly) in position at the center of one form. Figure 5 shows the same setup with two loading devices in place, 8 feet 8 inches apart, bearing on the ceiling of the laboratory and the top of the form. This spacing represents the wheel base of a finishing machine. The loads were applied singly and in pairs to approach as nearly as possible the field condition of two wheels of the finishing machine riding on the forms simultaneously. A sketch showing the various positions of loads and dials employed in the tests is given in Figure 6.

The loads were applied in three increments of 1000 pounds and one of 500 pounds, making a total of 3500 pounds for each loading point. Following each series of tests on each type of form a soil sample was taken from under the forms and the moisture content and density determined. All forms were

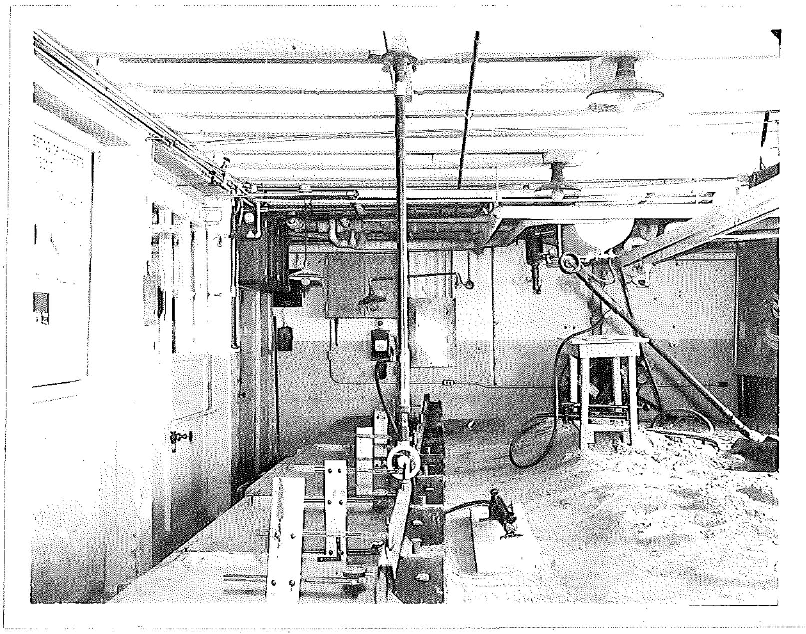

Figure 4. Single loading device in place between the ceiling and one of two L section forms connected end-to-end.

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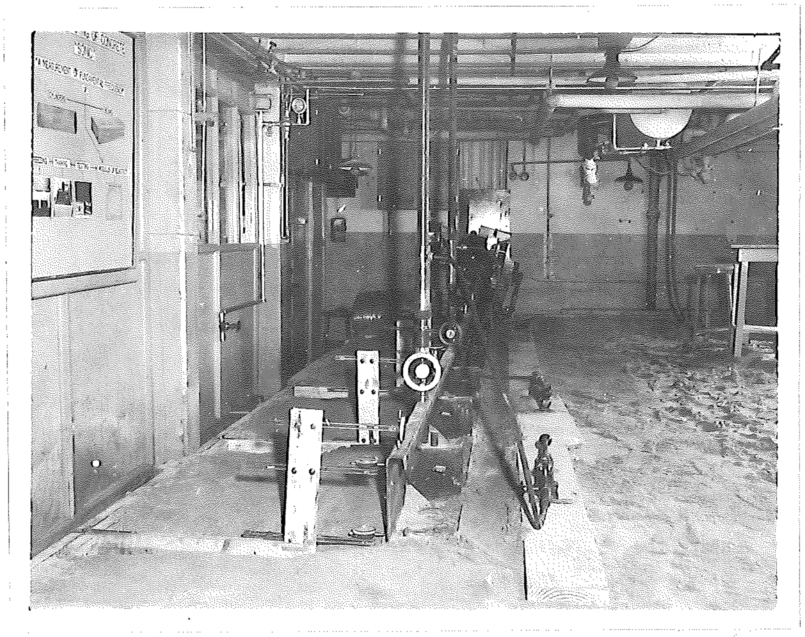
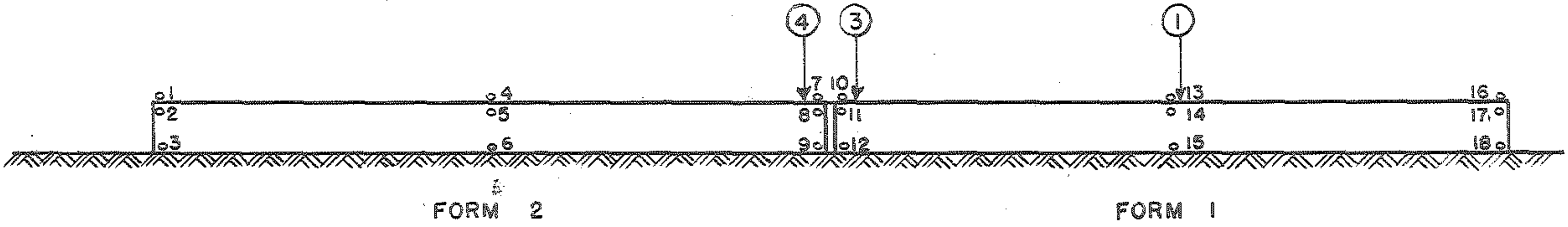
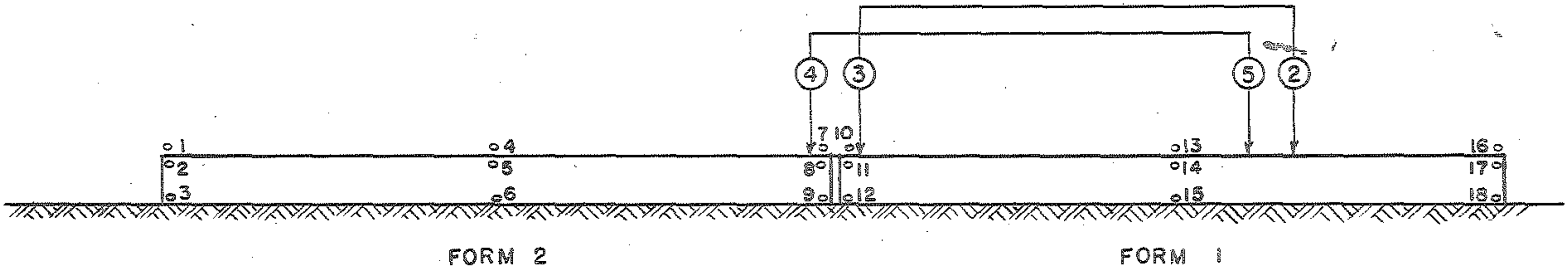


Figure 5. Two loading devices spaced 8'6" apart on one of two L section forms connected end-to-end.

SKETCH *of* TWO CONNECTED FORMS TESTED *on a* SAND SUBGRADE SHOWING POSITIONS *of* LOADS *and* DIALS



SINGLE LOADS



DOUBLE LOADS

↓ = POSITIONS OF 3500 POUND CONCENTRATED LOAD

○ = POSITIONS OF DIALS

FIGURE 6

omit for Blaw Knox

staked down with 24 inch pins. The trapezoidal form uses 7/8 inch diameter pins with a special mushroomed head, while all other forms require 1 inch diameter plain head pins.

Only two tests, one each for the trapezoidal and L types, were performed using two forms clamped face-to-face on the sand subgrade; the setup is shown in Figure 7.

In this series of tests an attempt also was made to determine the behavior of the forms under lateral thrust by simple means. This was an effort to simulate the lateral thrust of the equipment riding on the forms, but little or no reliable data were obtained by the simple method employed.

DISCUSSION OF RESULTS

All forms displayed elastic characteristics in the load range employed, and the load-deflection curves obtained were practically all straight lines with the exception of small variations at the initial increments. The results of the loading tests are given in the graphs of Figures ~~Tables 2, 3 and 4 and graphs for the simple beam tests are shown in Figures 8 through 17.~~

For the uniformly supported beams various conditions of moisture and density of the subgrade and load positions were tried. In Table 4 the test results on the A, B and D forms under five different conditions of loading are given. Combinations of load position numbers, such as 2-3, indicate that loads were applied at both positions simultaneously.

omit for Blaw K

An analysis of the data indicates that the type of cross section, plate thickness, omit for Blaw-Knox conditions of support, design and fabrication of the forms, and the design of the joint between forms all affect the behavior of concrete pavement

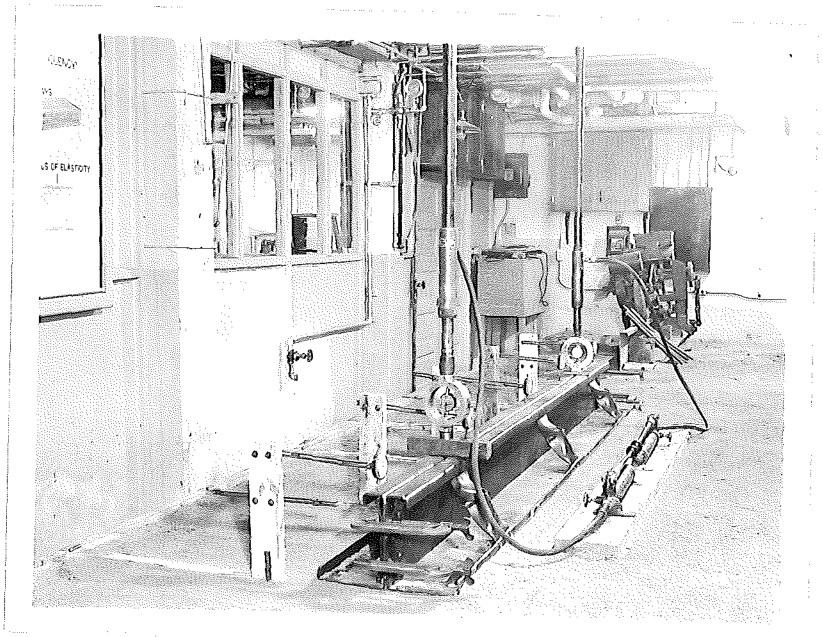


Figure 7. General view of two L type forms clamped face-to-face being tested on the subgrade.

TABLE 2

VERTICAL DEFLECTIONS OF CONCRETE PAVING FORMS UNDER LOAD

Single Form, Concentrated Load of 3500 Pounds at Center
Two Forms Clamped Face-to-Face, 7000 Pounds at Center

			Thickness of Metal - Inches					Maximum Vertical Deflections				
								Single Beam, 9'-6" Span			Uniformly Supported on Sand Subgrade*	
Form No.	Mfr.	Type of Section	Nominal	Actual	Height Inches	Base Inches	Wt. lbs. per 10 ft. Length	Single Form Inches	2 Forms Clamped Face-to-Face Inches	Reduction of Deflection Percent	Single Form Inches	2 Forms Face-to-Face Inches
7	B	Trap.	5/32	.142	10	8	169	.123				
1	B	Trap.	3/16	.183	10	8	207	.101	.085	16	.038	.029
2	A	L	3/16	.177	10	8	157	.301				
17	A	L	3/16	-	10	8	186	.134				
3	C	L	3/16	.200	10	8	161	.246				
4	C	L	3/16	.189	10	8	163	.211				
11	D	L	3/16	.183	10	8	173	.242	.189	22		
5	C	L	3/16	.201	9	8	155	.258				
13	C	L	3/16	.187	9	8	152	.256	.169	34		
9	D	L	7/32	.227	10	8	205	.152	.133	13	.048	
15	A	L	1/4	.260	10	8	215	.115	.090	19	.038	.018
22	C	L	1/4	.243	10	8	207	.148	.119	20		
25	C	L	1/4	.244	9	8	193	.182				
24	C	L	1/4	.248	9	9	203	.158				
18	A	L	1/4	.249	9	9	207	.134				
20	A	L	1/4	.255	8	9	204	.134				
19	A	L	1/4	.250	8	8	188	.163				
23	C	L	1/4	.250	8	8	187	.200				

* Deflections of center relative to ends.

TABLE 3

WARPING OF CONCRETE PAVING FORMS UNDER LOAD

Simply Supported Beam, Span 9'-6", Load at Center 3500 lbs.
Dial Positions and Sense of Indicated Values as in Figure 3

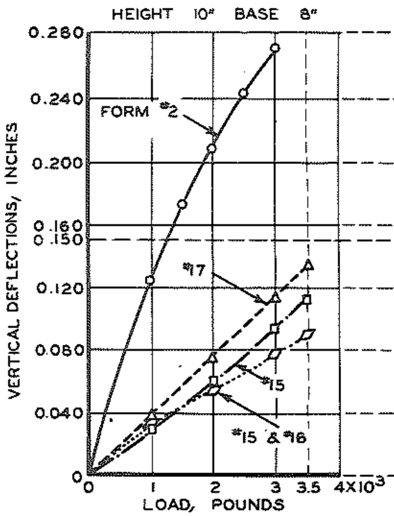
				Maximum Deflections, Inches						
				Center of Beam				Average of Both Ends		
				Vertical		Horizontal				
Form No.	Mfr.	Nominal Thickness of Metal, Inches	Type of Section	Top Surf.	Base Edge	Top Edge	Bottom Edge	Vertical Defl. Base Edge	Horizontal Defl. Top Edge	Maximum Warping Top Edge
7	B	5/32	Trap.	-.123	-	+.147	+.096	-	-	-
1	B	3/16	Trap.	-.101	-.110	+.056	+.057	.000	+.008	-.048
2	A	3/16	L	-.301	-	+.064	+.100	-	-	-
17	A	3/16	L	-.134	-	+.049	+.073	-	-	-
3	C	3/16	L	-.246	-	+.014	+.127	-	-	-
4	C	3/16	L	-.211	-	+.312	+.197	-	-	-
11	D	3/16	L	-.242	-	+.118	+.146	-	-	-
5	C	3/16	L	-.258	-	+.151	+.167	-	-	-
13	C	3/16	L	-.256	-.519	+.128	+.164	+.255	+.346	+.218
9	D	7/32	L	-.152	-.189	+.063	+.090	+.144	+.257	+.194
15	A	1/4	L	-.115	-.195	+.056	+.061	+.004	+.053	-.003
22	C	1/4	L	-.148	-.183	+.024	+.075	+.135	+.232	+.208
25	C	1/4	L	-.182	-.225	+.027	+.082	+.152	+.237	+.210
24	C	1/4	L	-.153	-.288	-.046	+.061	+.068	+.118	+.164
18	A	1/4	L	-.134	-.169	+.019	+.055	+.046	+.103	+.084
20	A	1/4	L	-.134	-.160	+.044	+.067	+.110	+.054	+.010
19	A	1/4	L	-.163	-.183	+.060	+.073	+.119	+.066	+.006
23	C	1/4	L	-.200	-.305	-.007	+.081	+.093	+.161	+.168

TABLE 4

DEFLECTIONS OF CONNECTED PAVEMENT FORMS LOADED ON SAND SUBGRADE

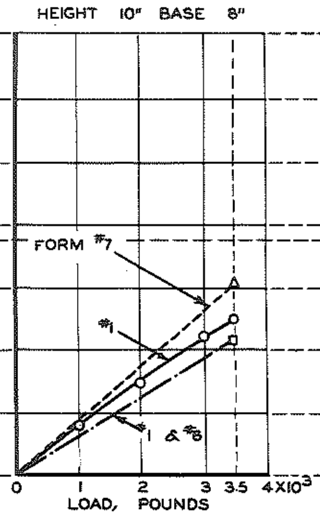
Load and Dial Positions as in Figure 6

					Maximum Deflections, Inches								Joint Movement	
					Center, Form 1				Joint End, Form 1		Joint End, Form 2		Relative Displacement of Form Ends at Top	
			Subgrade		Vertical		Horizontal		Top Edge		Top Edge			
Form No.	Mfr.	Load Position	Density p.c.f.	Moisture Percent	Absolute	Relative to ends	Top Edge	Bottom Edge	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal
1,6	B	1	94	7.3	-.084	-.038	+.131	+.034	-.043	+.061	-.015	+.053	.028	.008
9,10	D	1	97	8.5	-.074	-.048	+.080	+.031	-.027	+.061	-.023	+.053	.004	.008
9,10	D	1	94	4.6	-.151	-.097	+.130	+.097	-.038	+.176	+.010	+.045	.048	.131
15,16	A	1	92	6.9	-.066	-.038	+.094	+.027	-.015	+.056	-.002	+.037	.011	.019
1,6	B	3	91	6.8	-.025	+.017	+.069	+.057	-.288	+.262	-.234	+.261	.054	.001
9,10	D	3	92	6.9	+.093	+.005	-	+.074	-.431	+.360	-.240	+.396	.191	.036
5,16	A	3	-	-	-	-	-	-	-	-	-	-	-	-
1,6	B	4	91	6.8	-.020	+.007	+.247	+.086	-.174	+.253	-.274	+.301	.100	.048
9,10	D	4	92	6.9	+.080	+.017	+.111	+.033	-.271	+.328	-.438	+.358	.167	.030
15,16	A	4	-	-	-	-	-	-	-	-	-	-	-	-
1,6	B	2-3	94	7.3	-.161	-.009	+.280	+.074	-.186	+.155	-.151	+.257	.035	.102
9,10	D	2-3	92	6.9	-.233	+.035	-	-	-.316	+.331	-.217	+.317	.099	.014
5,16	A	2-3	92	6.9	-.080	+.024	-	+.032	-.136	+.140	-.083	+.125	.053	.015
1,6	B	4-5	94	7.3	-.138	-.019	+.255	+.068	-.136	+.268	-.313	+.335	.177	.067
9,10	D	4-5	97	8.5	-.071	-.030	+.094	+.033	-.071	+.147	-.214	+.155	.143	.008
5,16	A	4-5	92	6.9	-.075	-.002	+.157	+.040	-.094	+.168	-.162	+.164	.068	.004



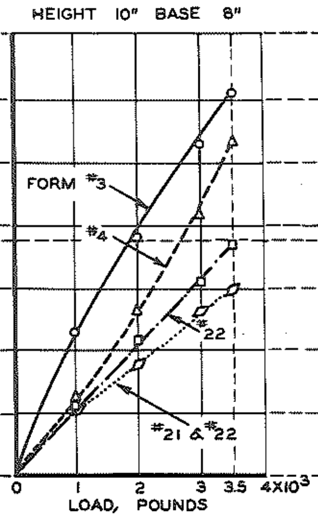
L SECTION-MFR. A

FIG. 8



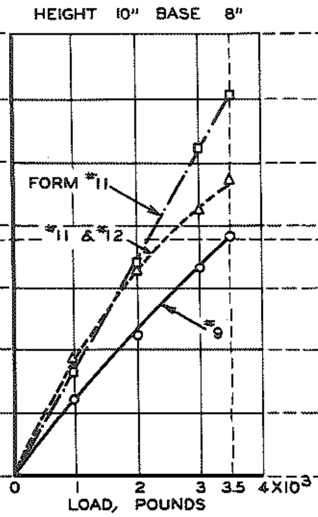
TRAPEZOIDAL SECTION
MFR. B

FIG. 9



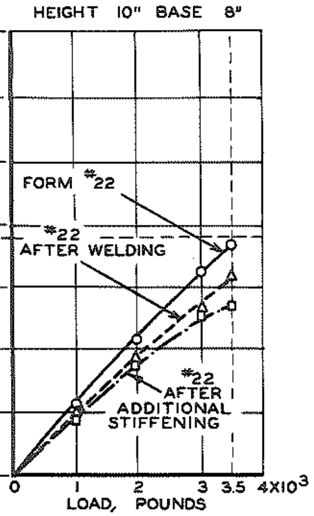
L SECTION-MFR. C

FIG. 10



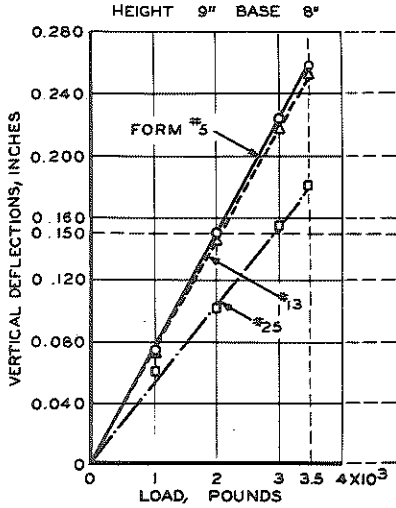
L SECTION-MFR. D

FIG. 11



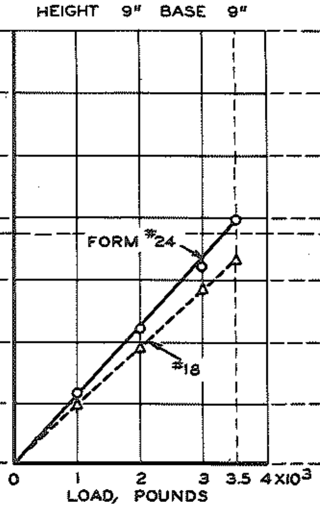
L SECTION-MFR. C
(MODIFIED)

FIG. 12



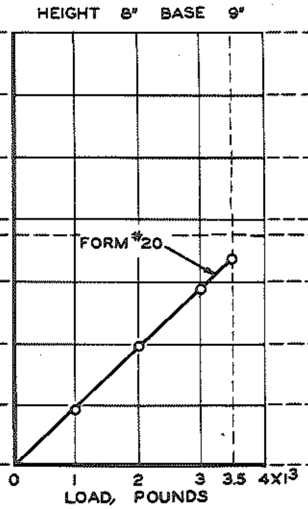
L SECTION-MFR. C

FIG. 13



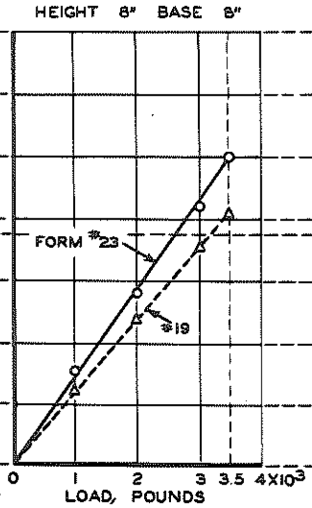
L SECTION
FORM 24 MFR C
FORM 18 MFR A

FIG. 14



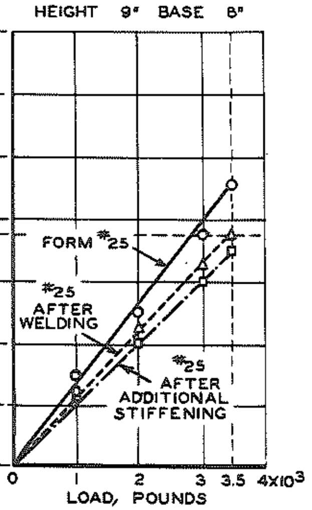
L SECTION-MFR. A

FIG. 15



L SECTION
FORM 19 MFR. A
FORM 23 MFR. C

FIG. 16



L SECTION-MFR. C
(MODIFIED)

FIG. 17

VERTICAL DEFLECTIONS *of* PAVING FORMS TESTED *as* SIMPLE BEAMS

forms under load, and the effect of these factors will be discussed in the succeeding pages.

Effect of Cross Section

All forms deflected horizontally as well as vertically when subjected to a vertical center load. This warping tendency is much more pronounced in the L section than in the trapezoidal forms, and in the L section it decreases with an increase in the thickness of the plate. The sketch in Figure 3 shows this warping or twisting action. Trapezoidal form B-1 showed the least amount of warping of all forms tested. However, the values obtained in the warping measurements were variable and the behavior of the forms in this respect was very erratic.

Table 2 and the graphs in Figures 8 through 17 show that L forms A-15, 17, 19, 20 and C-12 and trapezoidal forms B-1 and B-7 deflected less than .150 inch under the 3600 pound test load. All other forms tested failed to meet the tentative maximum deflection of .150 inch at 3600 pounds when tested singly as simple beams. The fact that both forms of the trapezoidal section qualified under this test, while only five of the forms of L section were able to do so, demonstrates the superior efficiency of the trapezoidal section. out

By clamping the forms together face-to-face vertical deflections were reduced, the reduction in vertical deflection varying from a minimum of 15 percent to a maximum of 34 percent for forms tested as simple beams in this manner. This is shown graphically in Figures ~~8~~ 1 through 12 4 and clearly indicates that if the warping tendency is restrained the vertical deflection characteristics are improved.

Effect of Plate Thickness

Vertical deflections of L type forms in the simple beam tests were, with a single exception, greater for forms of 3/16 inch plate thickness than for those of 1/4 inch thickness, the average difference for all forms tested amounting to almost .1 inch. As noted previously, the warping tendency also increases as the plate thickness decreases. It is evident that a minimum thickness of 1/4 inch is a necessary condition in order to produce the desired stability in the L forms, but not a sufficient one, since only five forms of this type and thickness were able to meet the minimum deflection requirements.

The discussion in the previous paragraph applies only to the L type form. Owing to the more efficient distribution of metal in the trapezoidal section, a somewhat thinner plate is sufficient to bring about the required rigidity. Although both forms of the trapezoidal type, one of 3/16 inch and the other of 5/32 inch metal, deflected less than 1/8 inch under the 3500 pound load, there are limitations here also from the standpoint of practical use. This point will be discussed more fully in a later section of the report containing some notes on old and new forms. out

Effect of Design and Fabrication Methods out

In the simple beam tests of single forms there was revealed an interesting result. It was noted that some of the new L type forms shipped to the laboratory directly from Manufacturer C failed to meet the .150 inch maximum deflection tests. The forms appeared to be well constructed of 1/4 inch plate and it was noted that the stake pockets were riveted to the base and to the face of the form but had no rigid connection to the back lip of the top rail nor were they attached to the upturned edge of the base. It was also noted that stake pockets of the same size were used on forms of both eight and nine inch base, probably for economy in construction (Figures 18 and 19). In doing this the greater stabilizing effect which would be secured by a wider stake pocket on the nine inch base is lost.

Since the forms were apparently as well constructed as some of the L section forms of another make which gave lower vertical deflections, the only difference being the method of attaching the stake pockets, An an attempt was made to improve their rigidity by welding the stake pockets to the top rail and, later, by adding angle iron stiffeners midway between the stake pockets. Photographs in Figures 18, 20 and 22 show these stages in the modification of the eight-inch base form.

Tests were made on two of the original forms, repeated after welding the stake pockets, and again after adding the stiffeners. The rigidity of both forms was sufficiently improved by these changes to result finally in vertical deflections well below the tentative limit of .150 inch. The improvement in performance of the two forms after each operation may be seen in the load-deflection curves of Figures 12 and 17. This experiment emphasizes the fact that forms of L section, even when constructed of 1/4 inch metal, must be designed and fabricated for maximum possible rigidity in order to properly support the given load. It may be noted also that the alterations on these forms make use of the trapezoidal principle of construction. omit

Effect of Conditions of Support

Vertical deflections at the center obtained by loading forms on the sand subgrade were in all cases lower than those obtained by testing the forms as simple beams. Tables 2 and 4, and the graphs of Figures 23, 24 and 25 show that the deflections of the center relative to the ends are small

omit for Blan

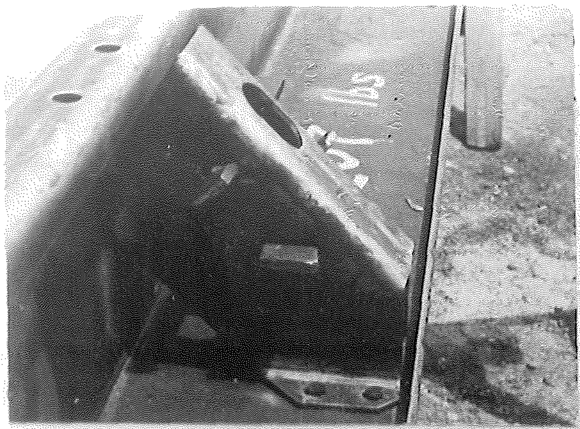


Fig. 18. Method of attachment of stake pocket on C forms.

Fig. 19. View showing gap between lower end of stake pocket and edge of base on a 9" base form

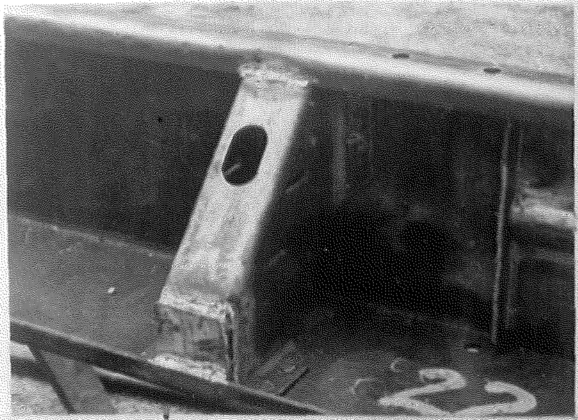


Fig. 20. Stake pocket welded.

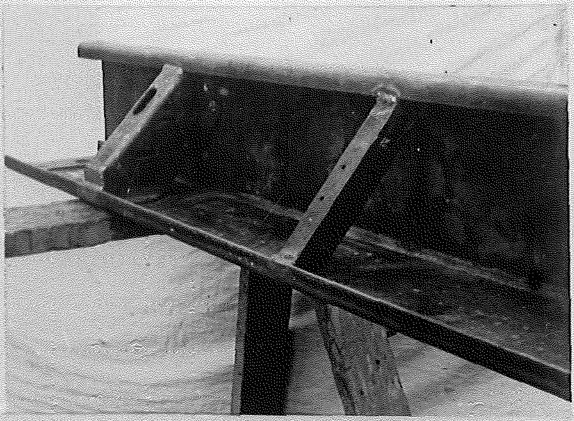


Fig. 21. Stake pocket welded and stiffener added.

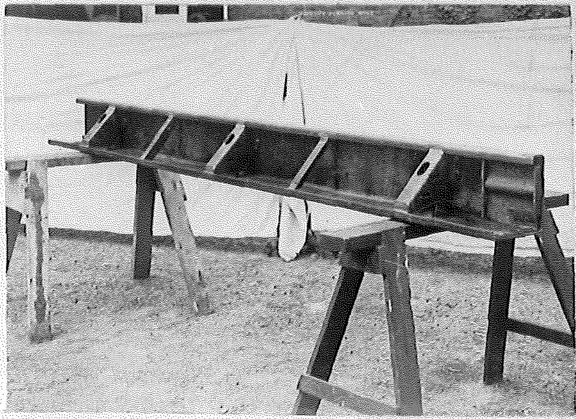
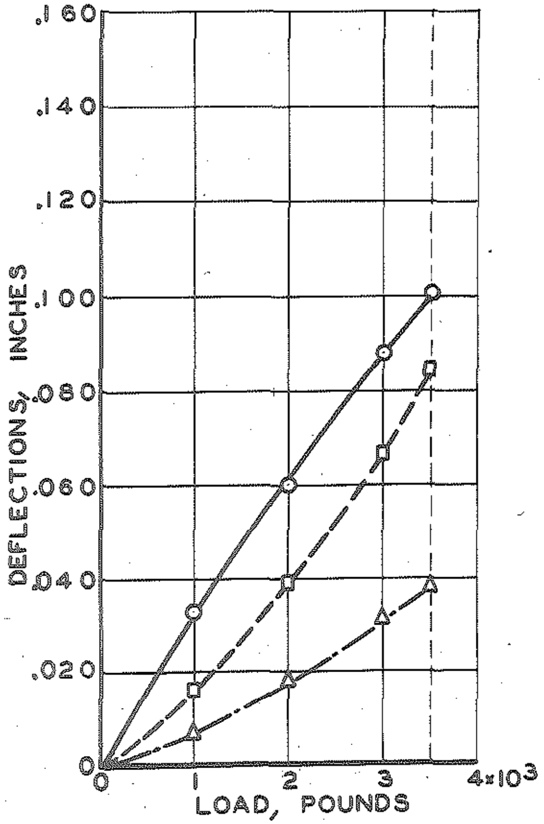


Fig. 22. General view of C form after being altered by welding 2 stiffeners and 3 stake pockets.

EFFECT *of* TYPE *of* SUPPORT *on* VERTICAL DEFLECTIONS

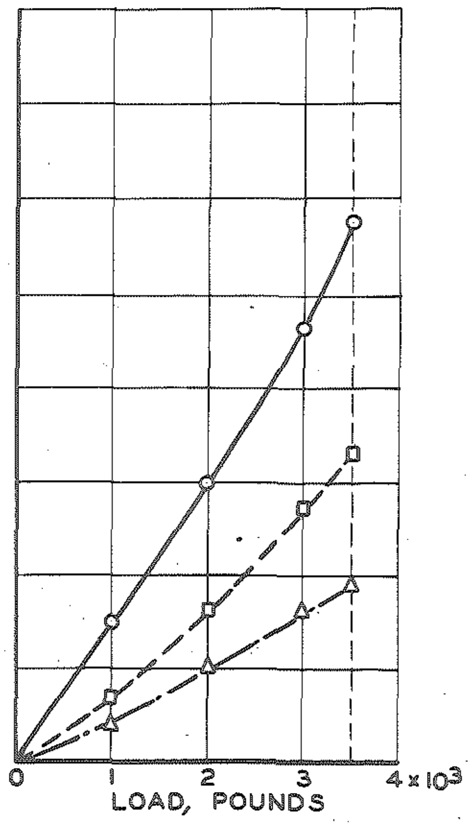
LOAD AT CENTER 3500 LBS. SUBGRADE MODULUS K= 100 P.C.I.

LEGEND:
o———o SIMPLE BEAM, HEIGHT 10 IN, BASE 8 IN.
□– – –□ ABSOLUTE DEFLECTIONS ON SUBGRADE
△—·—·△ DEFLECTIONS OF CENTER RELATIVE TO ENDS, ON SUBGRADE



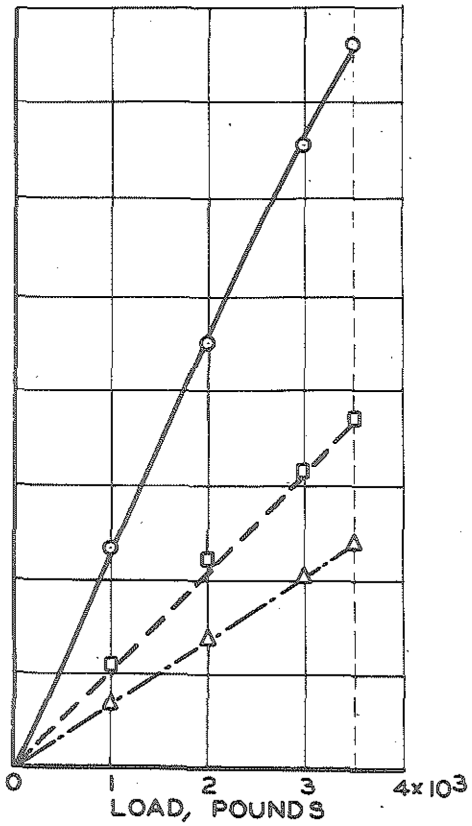
TRAPEZOIDAL SECTION
MFR B

FIG. 23



L SECTION
MFR. A

FIG. 24



L SECTION
MFR. D

FIG. 25

out for Blanchard

when the forms are uniformly supported, but that a subsidence of the whole form occurs which varies according to the condition of the subgrade. That the particular conditions of support exert a considerable influence on the behavior of the forms under load is clearly demonstrated by the difference in results obtained from tests of form D-8 on subgrades of the different densities and moisture contents.

The riding qualities of the finished pavement, however, will be affected more by variations in the supporting characteristics of a given subgrade along a line of forms than by the intrinsic properties of the subgrade material itself. It is conceivable that the extreme condition of hard spots of subgrade under both ends and a soft spot at the center could occur to cause the form to react essentially as a simple beam. It follows, then, that care should be taken to see that the forms are set to bear evenly on a uniformly prepared subgrade in order to secure minimum variation in vertical deflections.

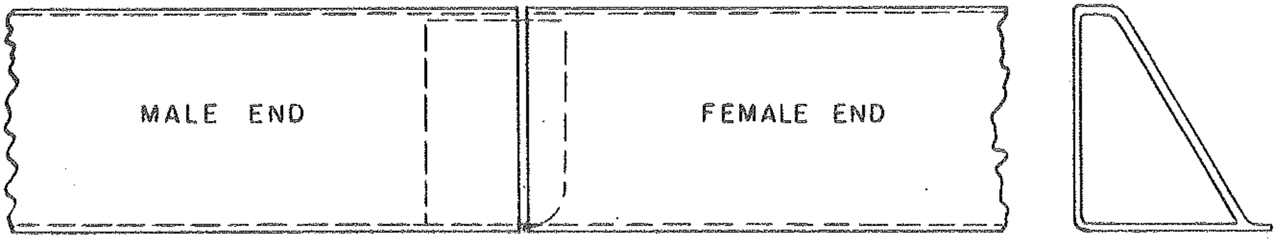
Effect of Joint Design

At load positions near the joint faulting is apt to occur between abutting ends of the forms, the extent of which depends largely on the design and condition of the connector and the amount of gap. Table 4 gives the deflections obtained by applying both single and double loads at various positions on two forms connected end-to-end. It should be kept definitely in mind, however, that the values of absolute depression of the form ends at the joint obtained in these tests, where the outer ends of both forms are free, are not indicative of vertical deflections to be expected in the field where any particular form is an interior one in a long row. The tests do indicate, though, the amount of vertical and horizontal play to be expected in the connection itself, and emphasize the importance of proper staking and joining of the forms, as well as the design and condition of the connector.

There is a distinct difference between the characteristics of the connectors used on trapezoidal and L section forms. Sketches in Figures 26 and 27 show the positions of the two types before and after loading. Whereas the connector plate in all of the L shaped forms is generally symmetrical and the movement at the joint is essentially the same whether the load is applied on one side of the joint or the other, the trapezoidal form joint has distinctly male and female ends and the amount of faulting depends on whether the load is applied on the male or female end.

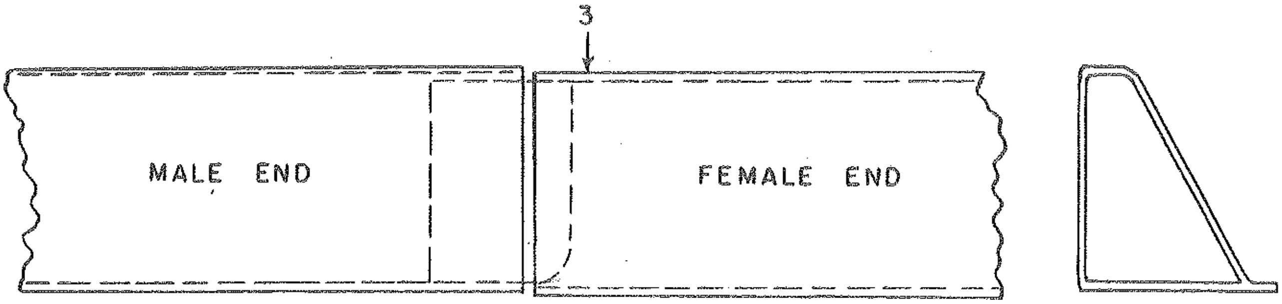
The rounded lower end of the trapezoidal form connector, while a desirable feature from the standpoint of ease of installation and removal of the forms, does not provide full load transfer when the load is applied on the male end of the form, especially when the ends are not butted tightly. The data in Table 4 show that the relative vertical displacement of the trapezoidal form ends is much greater for load positions 4 and 4-5 than for positions 3 and 2-3, which represent applications over the male and female ends respectively. The performance of the trapezoidal connector is also illustrated in Figures 28 through 35. It may be observed that when the forms are butted tight, the ends of the forms are not displaced vertically regardless of whether the support is under the male or female end of the form, but when the forms are not butted tight the male end drops when the support is under the female end. Even when the ends are butted tight the forms collapse at the joint when no support at all is provided. This joint should perform satisfactorily in service if the form ends are butted tight and the joint is

SKETCHES OF TRAPEZOIDAL - FORM JOINTS SHOWING ALIGNMENT BEFORE LOADING AND RELATIVE DISPLACEMENT UNDER LOADS ON EITHER SIDE OF THE CONNECTION



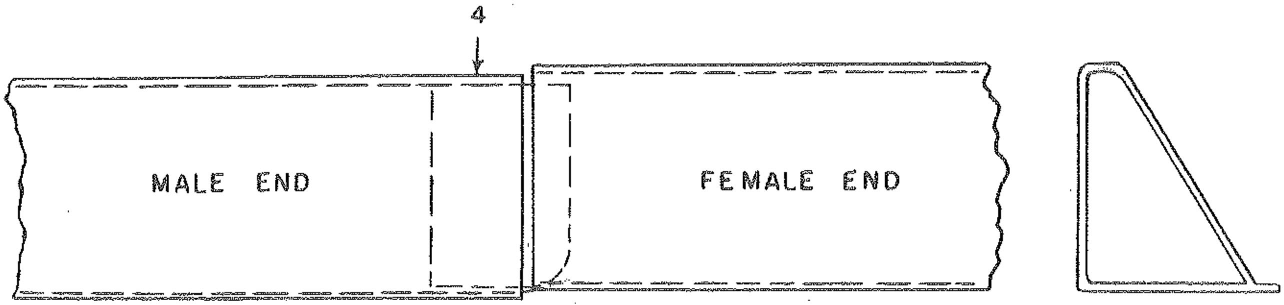
POSITION BEFORE LOADING

A



LOAD POSITION NO. 3

B

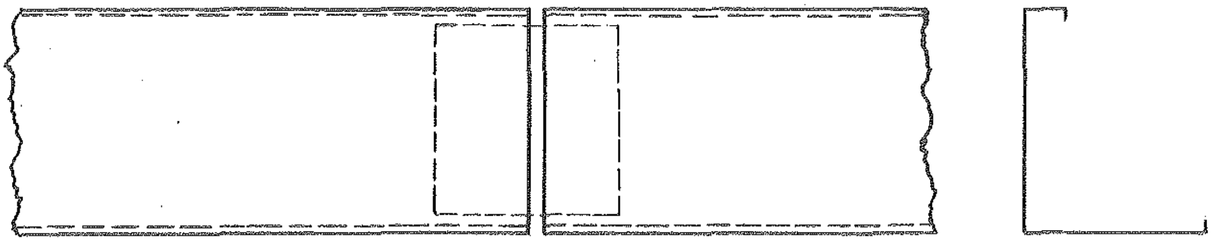


LOAD POSITION NO. 4

C

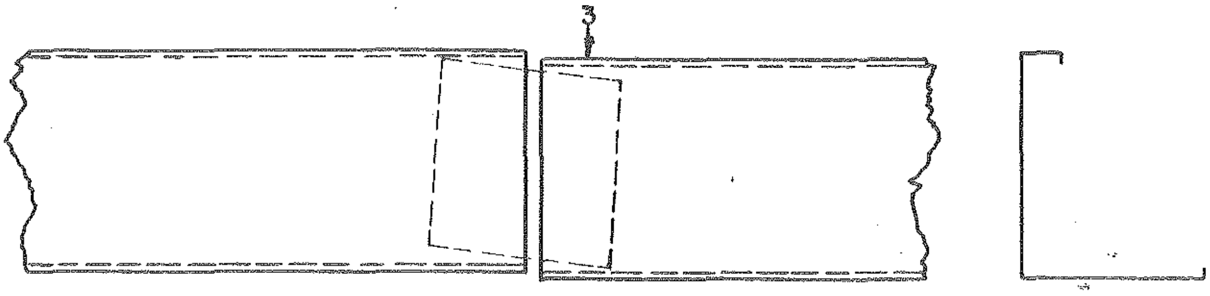
FIGURE 26

SKETCHES OF L FORM JOINTS SHOWING ALIGNMENT BEFORE LOADING AND RELATIVE DISPLACEMENT UNDER LOADS ON EITHER SIDE OF THE CONNECTOR



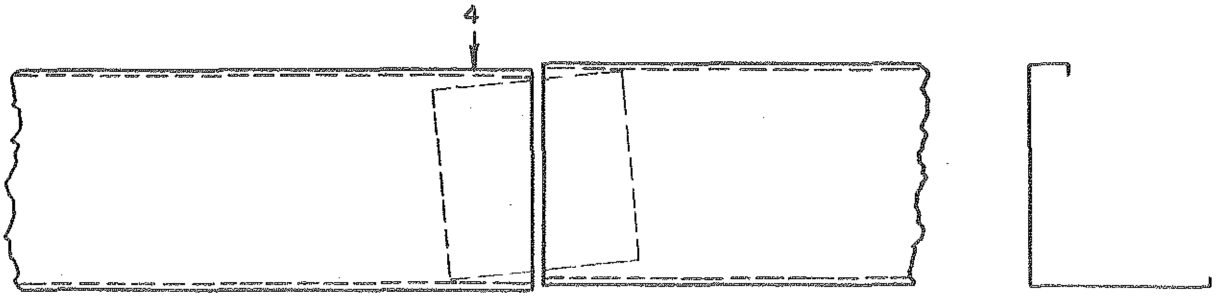
POSITION BEFORE LOADING

A



LOAD POSITION NO. 3

B



LOAD POSITION NO. 4

C

FIGURE 27

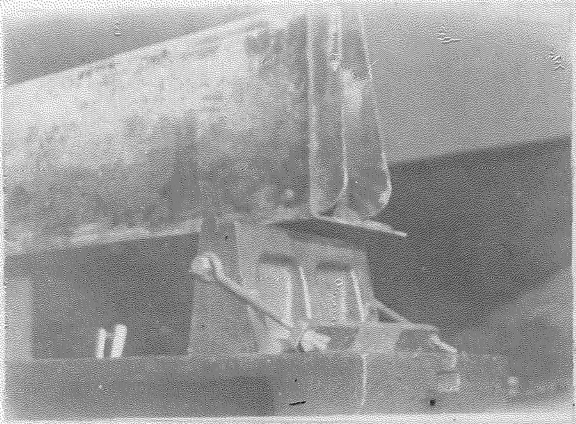


Fig. 28. View of male connector of trapezoidal form taken from the face side showing the rounded lower edge of splice.

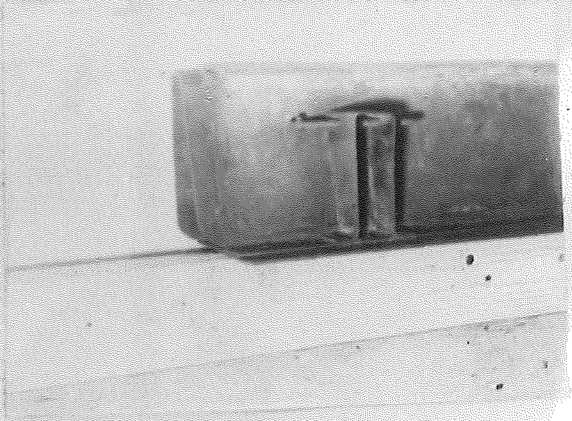


Fig. 29. View of male connector taken from the back side of form.

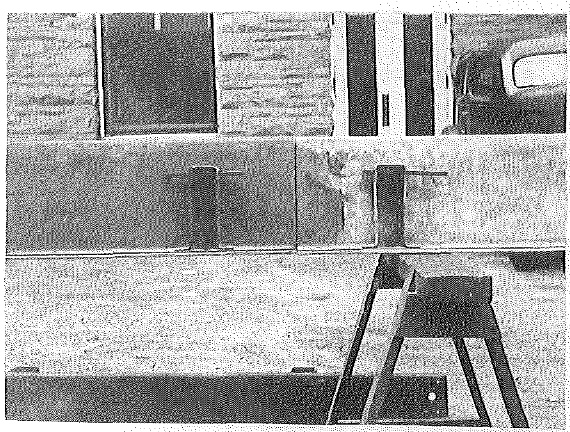


Fig. 30. Two trapezoidal forms with support under male end, forms butted tight.

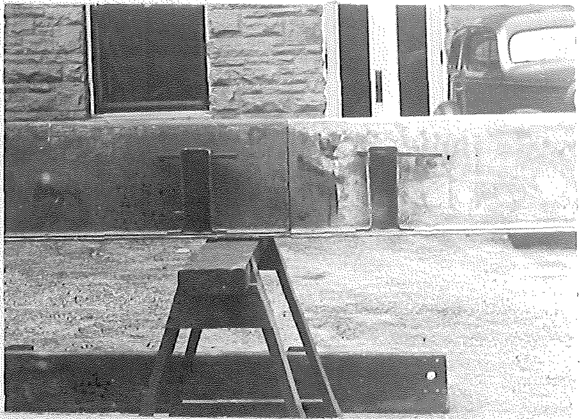


Fig. 31. Two trapezoidal forms with support under female end, forms butted tight.

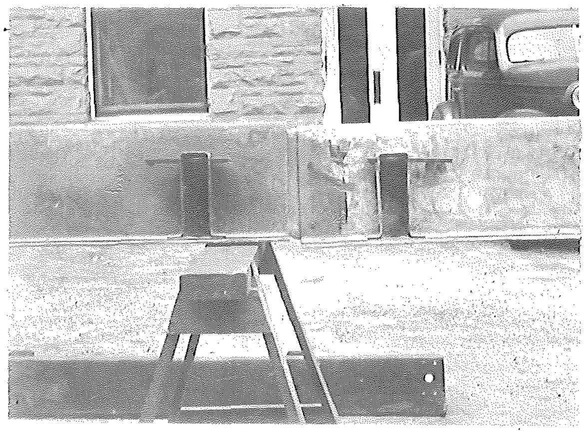


Fig. 32. Two trapezoidal forms spliced with a 1/2" gap, support under female end.

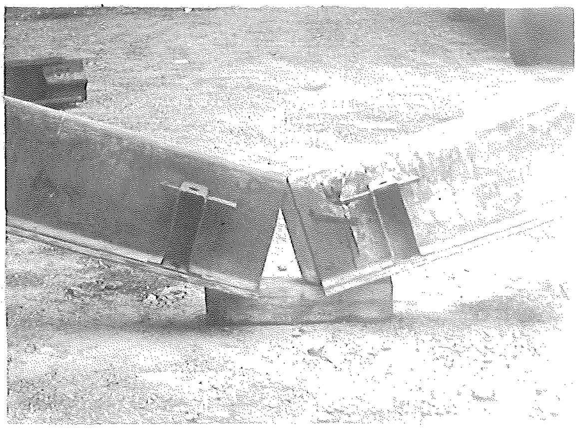


Fig. 33. Two trapezoidal forms [illegible] support under the joint.

firmly supported by the subgrade, but a loose joint on a soft spot of the subgrade could cause an excessive vertical deflection.

Figures 34 through 39 illustrate some joint characteristics of the three different makes of L forms. The two forms in each case were spliced and supported at the outside ends and at the connector. Then the center support was removed and the deflection at the joint measured. The deflections were as follows:

Form Make	A	C	D
Deflection, Inches	1-3/16	1-1/2	2-1/2

This comparison was made to show that the tolerance in the splicing plate varies with different forms.

Only six of the eleven States listed in Table 1 have clauses in their specifications governing joint performance. Of these, four specify that there shall be no play or movement in any direction, which is obviously impracticable and without definite meaning. It appears advisable to set a limit on permissible vertical deflections at the joint whether they be due to faulting of the form ends or depression of the whole joint, or both. It is reasonable and logical to require that the vertical and horizontal displacement should not be greater at the joint than elsewhere. In view of the existing requirements restricting vertical deviations to a maximum of 1/8 inch in 10 feet for the top surfaces of both pavement and form, it is also logical to select 1/8 inch as the maximum allowable vertical deflection at the joint under the load of the heaviest machine carried on the forms.

Lateral deviations are not so critical, but, in order to minimize irregularities in the pavement edge, these deviations should also be

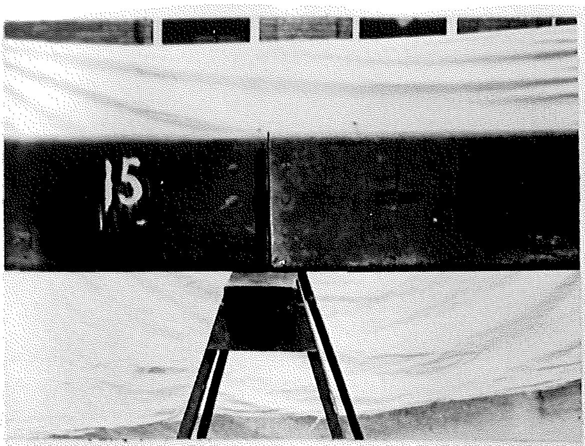


Fig. 34. Two connected L section A forms with support under splice.

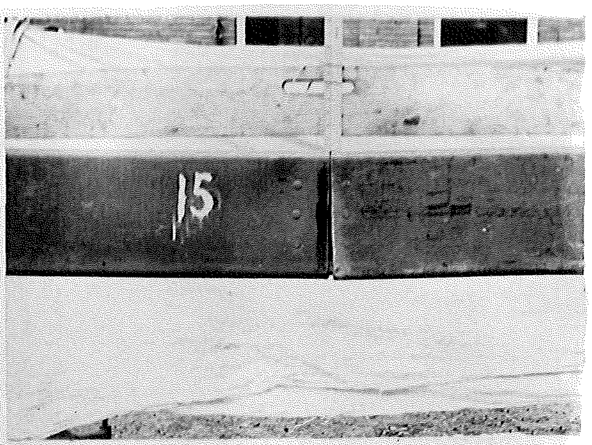


Fig. 35. Two connected L section A forms without support under splice, showing a 1-3/16" maximum deflection.

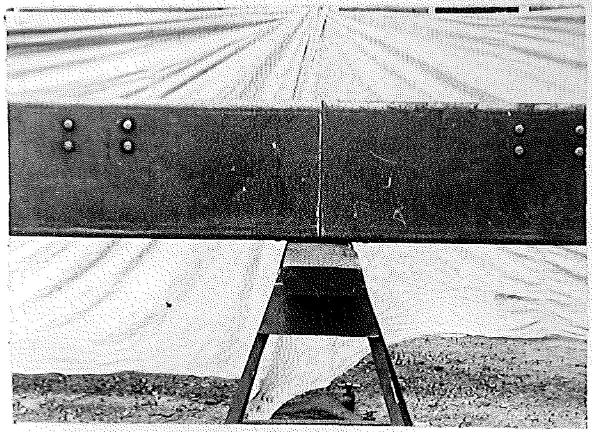


Fig. 36. Two connected L section C forms with support under splice.

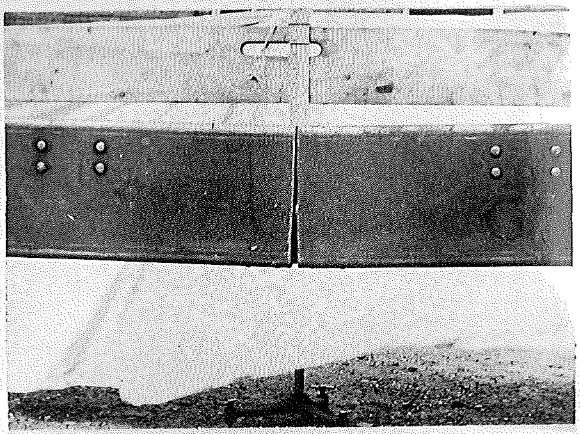


Fig. 37. Two connected L section C forms without support under splice, showing a 1-1/2" maximum deflection.

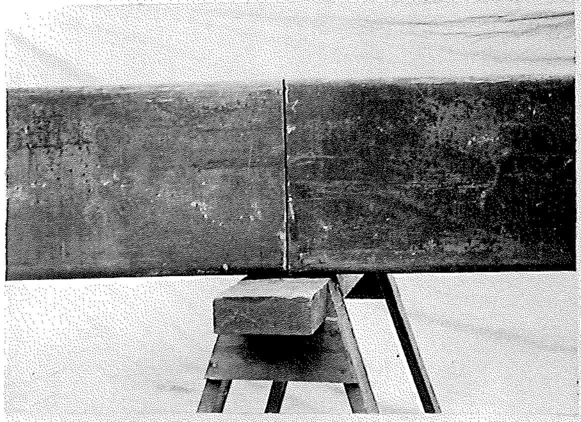


Fig. 38. Two connected L section D forms with support under splice.

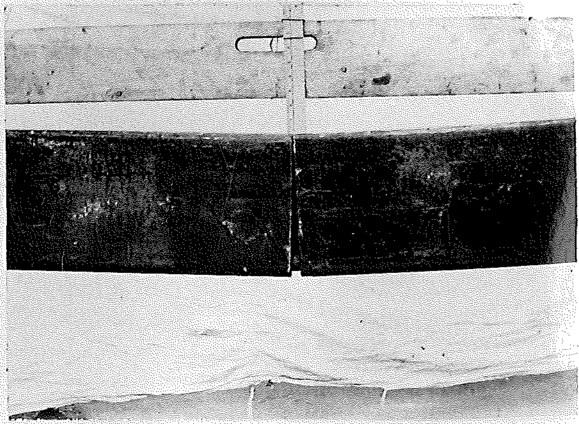


Fig. 39. Two connected L section D forms without support under splice, showing a 2-1/2" maximum deflection

restricted to a maximum of 1/4 inch, both in the planeness of the upstanding surface of the form and in the lateral position of the joint.

COMPARISON OF OLD AND NEW FORMS

A study of some of the old forms which had been in use for ten or twelve years or more reveals some interesting facts concerning their performance under field conditions. Figure 40 shows the end of an old A form which is warped and bent from use. The form is under a 2500 pound load at the center. This also shows the characteristic twisting of the form under load. Figure 41 shows the end of a D form. This reveals the wear on the splice plate caused by continued pounding necessary in joining the forms. Figures 42 and 43 show details of a new C form connector and Figure 44 shows one of the earliest C form connectors. The rib in the center of the splice plate is a solid square bar and is much more serviceable than the corrugation of the splice plate used on later forms.

Figure 45 shows an old A form stake pocket. Some of the rivet holes have sheared and the stake lock is badly bent, but the attachment of the stake pocket to the upturned edge of the base and to the back lip of the top rail is an efficient feature. Figure 46 shows the details of an old C form stake pocket. Note the double stake lock keys. This feature is retained in the latest forms of this type and the manufacturer claims that it is an efficient feature. Figure 47 shows another old C form stake pocket. The upper end of the pocket is attached to the back lip of the top rail, but the lower end is riveted to the base close to the face of the form. This stake pocket adds little resistance to lateral bending. Note that the rivets have

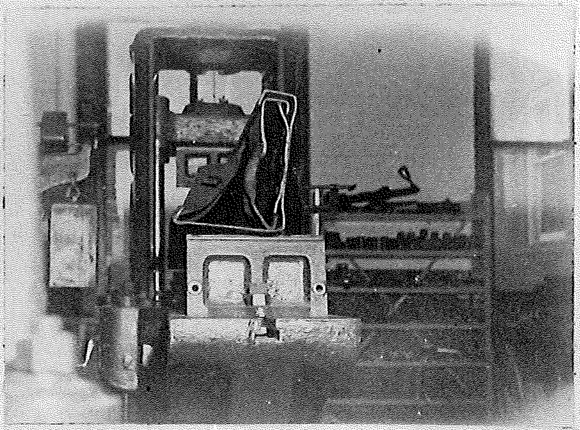


Fig. 40. End view of old A form splice.

Fig. 41. View of old D form splice showing battered condition of splice plate.

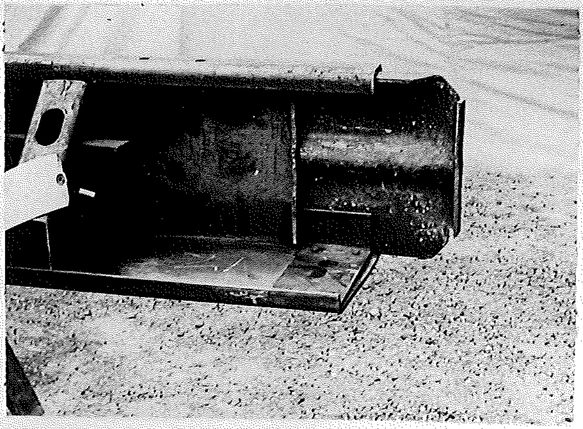


Fig. 42. New C connector.

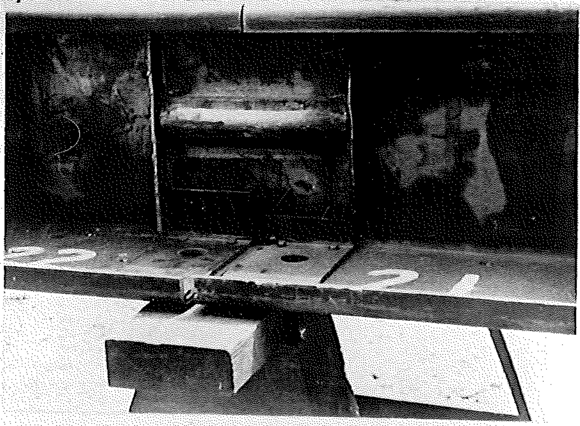


Fig. 43. C form splice showing beveled ends of forms to allow for alignment of forms on curves.

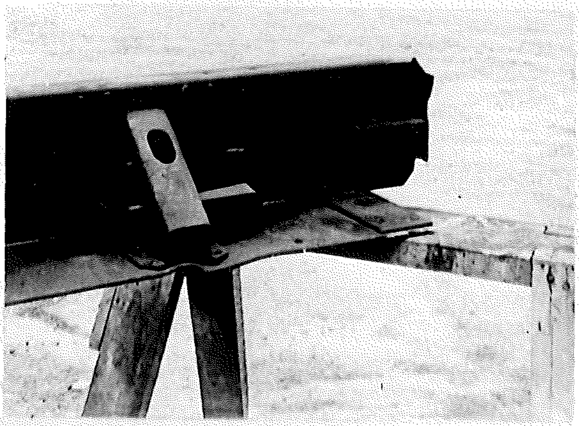


Fig. 44. An old design of C form connector. Note solid stiffening bar on splice plate.

pulled out from the lower end. Figure 48 shows a D form stake pocket. This is attached to the base, face and back lip of the top rail. This type of pocket was in good condition on all of the forms examined.

Figures 49 and 50 reveal an interesting behavior common to all L type forms. Through use the back edge of the top rail on which the wheels of the finishing machine ride has assumed a permanent bend upwards, and the horizontal surface of the top rail assumes a permanent concave section as seen under the straight edge in Figure 54. This tendency is not displayed in the trapezoidal forms.

Figures 51 and 52 show the light weight trapezoidal form which is constructed of 5/32 inch plate. These pictures show that this section, although it performs well in the simple beam tests, is too light to withstand the abuse to which forms are subjected in handling. A permanent maximum warp of approximately 1/2 inch has developed in both the longitudinal line of the top rail and in the face of the form. This indicates that there is a minimum limit to the thickness of plate that will produce serviceable forms even in the efficient trapezoidal section. Figure 55 shows how some of the old L type forms of less than 1/4 inch plate became dented and warped through use.

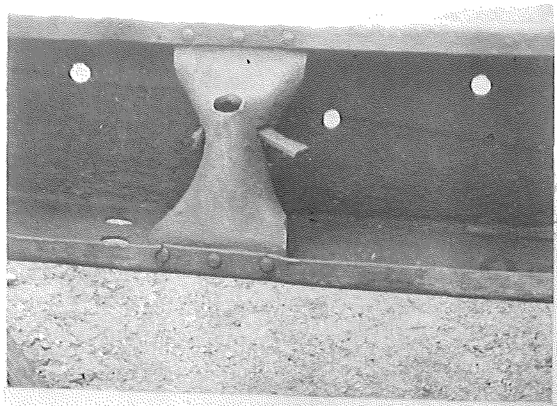


Fig. 45. View of stake pocket on an old A form showing unserviceable pin lock and sheared rivet holes.

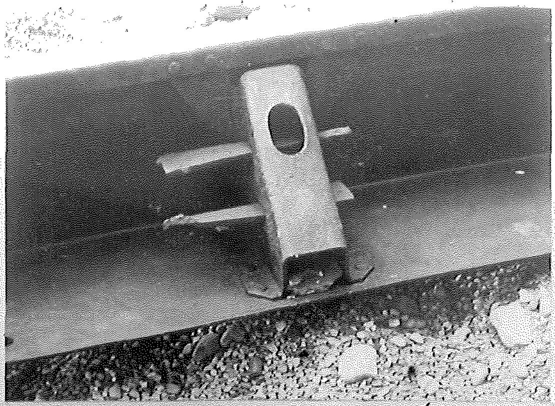


Fig. 46. View of stake pocket on an old C form showing method of attachment and the double stake locks.

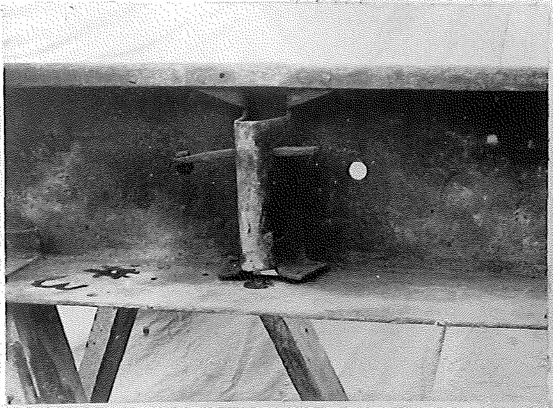


Fig. 47. Another type of stake pocket on an old C form; note sheared rivets at the lower end of pocket.

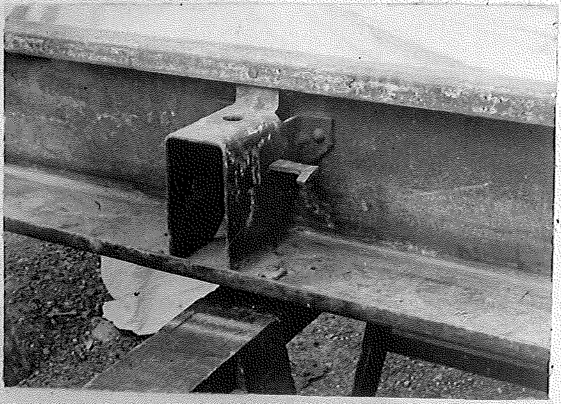


Fig. 48. Method of attachment of stake pocket to base face and top rail of a D form.

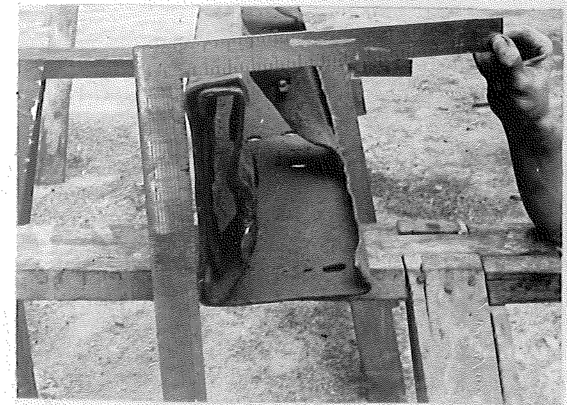


Fig. 49. End view of an old A form showing dented and warped condition and tendency of outside edge of top rail to bend upwards.

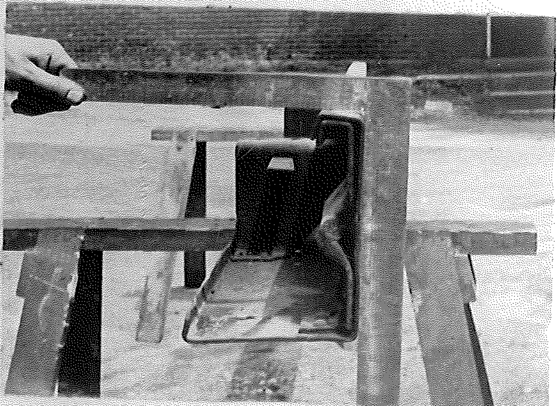


Fig. 50. End view of an old D form showing the upward bending of outside edge of top rail common to all L section forms.

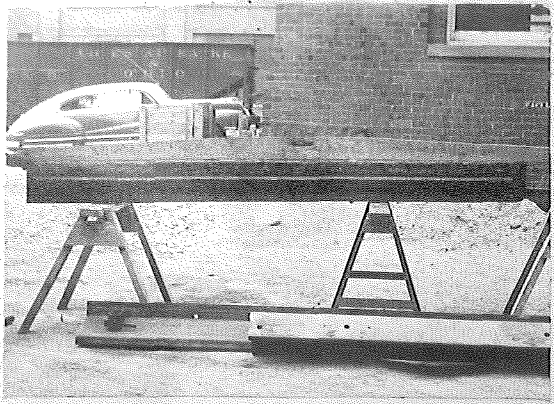


Fig. 51. View of a light weight trapezoidal form showing permanent vertical warp of approximately 1/2".

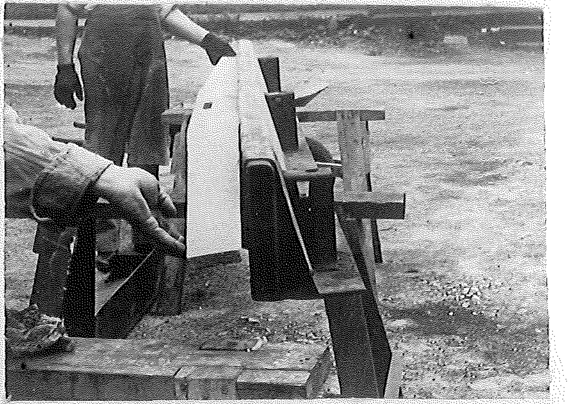


Fig. 52. Another view of the light trapezoidal form showing a permanent warp in the face of the form.

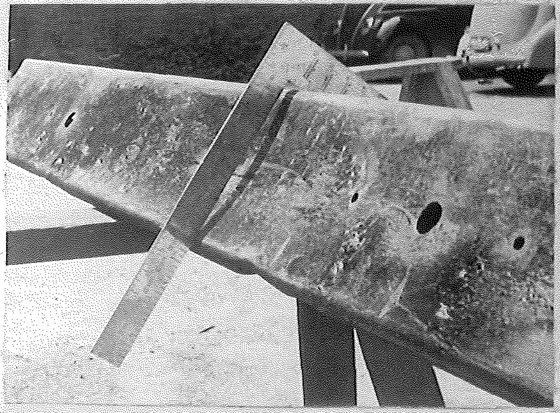


Fig. 53. View of an L section form showing typical dents and warp.

Fig. 54. View of L section form showing characteristic concave top resulting from field use.

SUMMARY

Concrete paving forms have been tested in the laboratory as simple beams of 9 feet 6 inch span with a concentrated load of 3500 pounds at the center and as uniformly supported beams on a sand subgrade under various conditions of loading. The load of 3500 pounds corresponds to the vertical force exerted by a single wheel of the heaviest modern finishing machine in present use. The significant results of the tests conducted to date are briefly summarized as follows:

1. Setting a limit of .150 inch for the permissible maximum vertical deflection in the simple beam test, in conjunction with minimum requirements of metal thickness, will eliminate the use of poorly designed, unstable forms.
2. Forms of L section must be constructed of metal at least 1/4 inch in thickness and designed for maximum rigidity in order to meet the tentative limit of .150 inch maximum vertical deflection in the simple beam test; those of trapezoidal section must be of at least 3/16 inch thickness to meet the requirements of the deflection test and to minimize denting and warping from handling and use.
3. In these tests forms of trapezoidal section were superior to those of L section in rigidity.
4. The conditions of support exert a considerable influence on the deflection of the forms under load, and care should be taken that the forms are set to bear evenly on a uniformly prepared subgrade.

B. When the forms are uniformly supported vertical deflections at the joint under a given load depend principally on the design and condition of the connector and such deflections should be limited to 1/8 inch under the load imposed by the heaviest machine carried on the forms.

C. Lateral deviations, both in the planeness of the face of the form and in the position of the joint, should be restricted to a maximum of 1/4 inch.

RECOMMENDATION

On the basis of the findings in this study it is recommended that the current Department specifications for concrete paving forms be amended to read as follows:

4.14.03 (a) 4. Form - Forms shall be of metal, of an approved section which will insure their rigidity under the impact, thrust and weight of the heaviest machine carried on them. Metal forms shall be of such rigidity that when tested as a simple beam of 3 foot 5 inch span under a center load of 3500 pounds the maximum vertical deflection shall not exceed .150 inch. The thickness of the metal shall be not less than one-quarter of an inch (1/4") except that a minimum thickness of three-sixteenths of an inch (3/16") will be permitted if the form is of trapezoidal cross section.

Forms shall have a minimum length of 10 feet and shall have a depth equal to the edge thickness of the work prescribed. The width of the base in direct bearing on the soil shall be not less than 8 inches. Each 10 foot section of form shall have at least three stake pockets. The forms shall be straight, free from distortion, and shall show no vertical variation greater than one-eighth of an inch (1/8") in 10-foot lengths from the true plane surface on the top of the form when tested with a 10 foot straightedge and shall show no lateral variation greater than one-quarter of an inch (1/4") from the true plane surface on the vertical face of the form when tested with a 10 foot straightedge.

The method of connection between form sections shall be such that a locked joint is formed free from vertical movement in excess of one-eighth of an inch (1/8") and from horizontal movement in excess of one-quarter of an inch (1/4") under the impact, thrust and weight of the heaviest machine carried on the forms.

Sufficient forms shall be provided so that it will not be necessary to remove them in less than 12 hours, or longer if required, after the concrete has been placed.

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